Foraminifera of the Gulf of Cambay

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(*With* 16 *figures in two plates*)

[*Continued from Vol.* 67 (2) : 273]

Family Rotaliidae

Subfamily Rotaliinae

Genus *Rotalia* Lamarck 1804

Rotalia beccarii (Linnaeus) (Fig. 69)

Rotalia beccarii Brady, 1884, vol. 9, p. 704, pl. 107, figs. 2, 3 ; Cushman, 1915, 71(5), p. 67, pl. 30, fig. 3 ; 1931, 104(8), p. 58, pl. 12, figs. 1-7, pl. 13, figs. 1, 2 ; Sethulekshmi Amma, 1958, p. 73, pl. 3, fig. 112 ; Ganapati & Satyavati, 1958, p. 110, pl. 5, figs. 122, 123.

Description : Test many chambered with both faces convex, all chambers visible on dorsal side but only those of the last whorl on ventral side. Outer whorl of eight to twelve chambers. Sutures on the dorsal side limbate, those on ventral side depressed. Umbilicus closed by a mass of shell material or umbonal plug. Wall smooth. Aperture a narrow slit situated on ventral side at inner margin of last chamber.

Diameter : 0·54 mm.

Locality : Stations A & D.

Distribution : North Pacific, Cebu, Philippine Islands, off Japan, Mediterranean and Red sea, British Isles, Ceylon coast and Arabian sea

Rotalia venusta Brady (Fig. 70 a, b).

Rotalia venusta Brady, 1884, vol. 9, p. 708 and 709, pl. 108, figs. 2 *a*, *b*, *c* ; Heron—Allen & Earland, 1915, vol. 20, p. 720, figs. 15-22.

Description : Test slightly biconvex, compressed with two coils, the outer coil formed of eight chambers. Sutures slightly depressed and

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distinct on both faces. Wall granulated on the ventral side. Aperture an elongate slit at the inner edge of last chamber.

Diameter : 0·14 mm.

Locality : Station D.

Distribution : South Pacific, Kerimba Archipelago and Arabian sea.

Genus *Pulvinulina* Parker and Jones, 1862

Pulvinulina concamerata (Montagu) (Fig. 71)

Rotalina concamerata Williamson, 1858, p. 52, pl. 4, figs. 102, 103 ; *Pulvinulina repanda* var. *concamerata* Brady, 1884, vol. 9, p. 685, pl. 104, figs. 19, *a-c* ; *Pulvinulina concamerata* Cushman, 1915, 71(5), p. 52, pl. 25, fig. 1.

Description : Test biconvex with six to eight chambers in final whorl. Sutures depressed on ventral side and limbate on dorsal side. Surface of test smooth on ventral side while on dorsal side ornamented with numerous rounded bosses.

Diameter : 0·13 mm.

Locality : Station D.

Distribution : North Pacific, off Japan, British Isles and Arabian sea.

Pulvinulina oblonga (Williamson) var. **scabra** Brady (Fig. 72)

Pulvinulina oblonga (Williamson) var. *scabra* Brady, 1884, vol. 9, p. 689, pl. 106, fig. 8 *a-c*; Brady, Parker & Jones, 1888, vol. 12, p. 229, pl. 46, fig. 5 ; Cushman, 1915, 71(5), p. 53, pl. 27, fig. 5.

Description : Test biconvex, chambers few about seven or eight in the outer whorl, the later formed chambers large in size and length. Peripheral edge acute, slightly carinate. Sutures somewhat depressed. Wall granular on the dorsal side and smooth on the ventral side.

Diameter : 0·38 mm.

Locality : Station C.

Distribution : North Pacific, off Philippines, Ceylon coast and Arabian sea.

Pulvinulina punctulata (d'Orbigny) (Fig. 73)

Pulvinulina punctulata Brady, 1884, vol. 9, p. 685, pl. 104, fig. 17 *a-c* ; Cushman, 1915, 71(5), p. 52, pl. 24, fig. 1.

Description : Test planoconvex, chambers numerous. All chambers visible on the dorsal side but only those of the final whorl on the ventral side. Sutures limbate and curved above and depressed below. Surface smooth but the umbilical region somewhat granular. Aperture a curved slit on ultimate chamber.

Diameter : 0·26 mm.

Locality : Station C.

Distribution : North Pacific, Hawaiian Islands and Arabian sea.

Family GLOBIGERINIDAE

Subfamily Globigerininae

Genus *Globigerina* d'Orbigny, 1826

Globigerina bulloides d'Orbigny (Fig. 74 a, b)

Globigerina bulloides Williamson, 1858, p. 56, pl. 5, figs. 116-118 ; Brady, 1884, vol. 9, p. 593, pl. 77, pl. 79, figs. 3-7 ; Brady, Parker & Jones, 1888, vol. 12, p. 225, pl. 45, fig. 15 ; Cushman, 1914, 71(4), p. 5, pl. 2, figs. 7-9, pl. 9 ; Sethulekshmi Amma, 1958, p. 12, pl. 1, fig. 20 *a*, *b* ; Ganapati & Satyavati, 1958, p. 110, pl. 6, figs. 142-146.

Description : Test subtrochoid spire with few chambers. All chambers visible dorsally and only three or four chambers on the ventral side ; chambers of the outer whorl much inflated. Sutures deep and distinct. Wall calcareous and hispid. Aperture large situated on the inner margin of last chamber.

Diameter : 0·26 mm.

Locality : Stations A, C & D.

Distribution : This species is world wide in distribution.

Globigerina dubia Egger (Fig. 75)

Globigerina dubia Brady, 1884, vol. 9, p. 595, p. 79, figs. 17 *a-c* ; Cushman, 1914, 71(4), p. 6, pl. 4, figs. 1-3 ; 1924, 104(5), p. 8, pl. 2, figs. 5-8 ; Sethulekshmi Amma, 1958, p. 13, pl. 1, fig. 21.

Description : Test subglobular with many chambers, all the chambers visible dorsally and only those of the ultimate whorl about five or six inflated chambers on the ventral side. Wall calcareous, coarse and pitted. Aperture opening into the much depressed umbilical region on the ventral side.

Diameter : 0·11 mm.

Locality : Stations B, C & D.

Distribution : Indo-Pacific region, North and South Atlantic, British Isles, and Hawaiian Islands.

Genus *Globigerinella* Cushman, 1948

Globigerinella aequilateralis (Brady) (Fig. 76)

Globigerina aequilateralis Brady, 1884, vol. 9, p. 605, pl. 80, figs. 18-21. ; Cushman, 1914, 71(4), p. 12, pl. 2, figs. 1-3, pl. 10, fig. 5 ; 1924, 104(5), p. 25, pl. 4, figs. 7-8. *Globigerinella aequilateralis* Sethulekshmi Amma, 1958, p. 15, pl. 1, fig. 25; Ganapati & Satyavati, 1958, p. 111, pl. 6, figs. 152-154.

Description : Test somewhat circular in shape, many chambered with five to six planospirally arranged chambers visible from lateral aspect. Sutures deep and depressed. Peripheral margin rounded. Wall calcareous, hispid with broken spines. Aperture large and arched, situated at the base of ultimate chamber.

Diameter : 0·68 mm.

Locality : Station B.

Distribution: Indo-Pacific region, Atlantic, Honolulu, off Yokohoma, Guam, Philippine Archipelago, Galapagos Islands, and Kerimba Archipelago.

Family Globorotaliidae

Genus *Globorotalia* Cushman, 1927

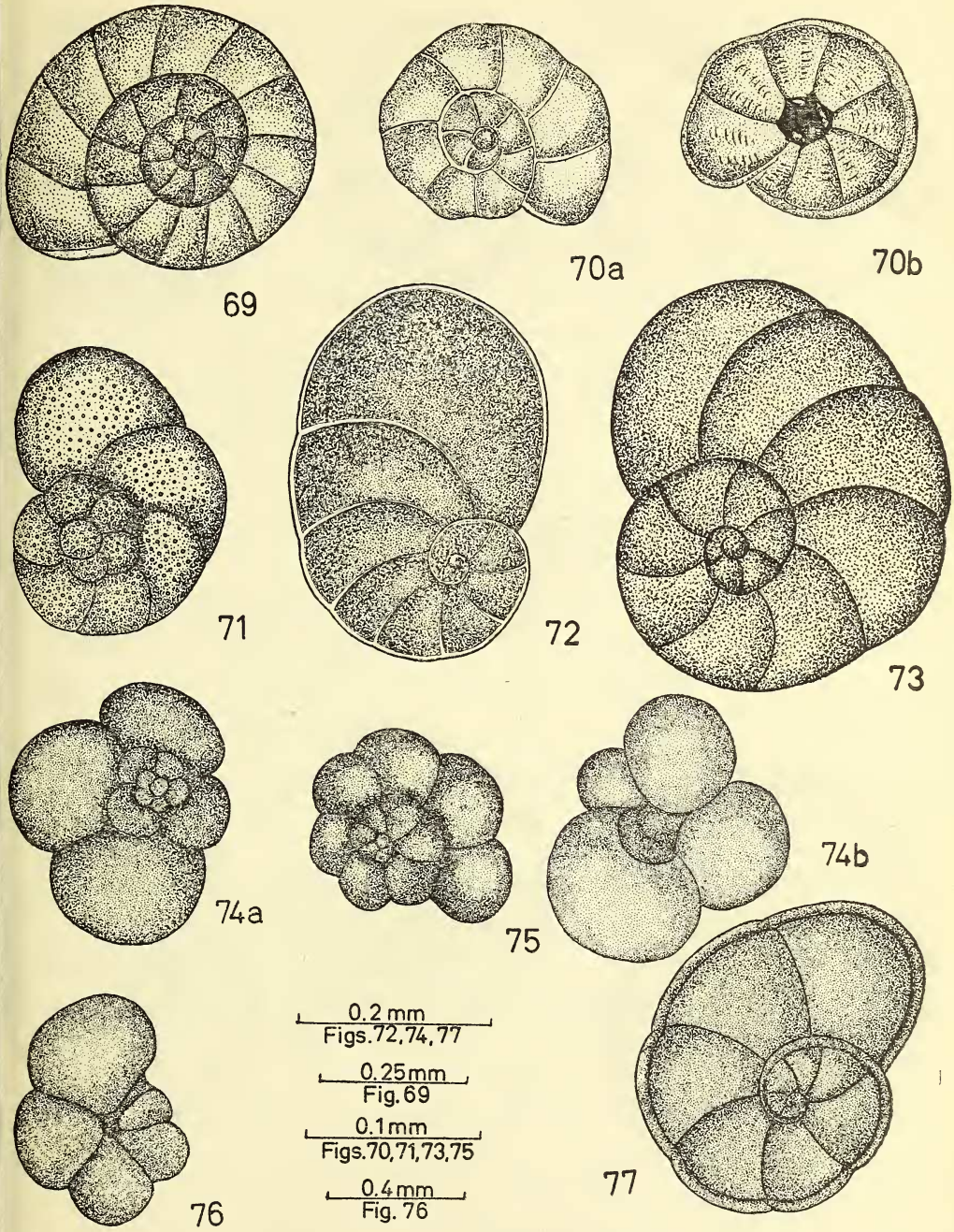
Globorotalia menardii (d'Orbigny) (Fig. 77)

Pulvinulina menardii Brady, 1884, vol. 9, p. 690, pl. 103, figs. 1, 2 ; Dakin, 1906, vol. 5, p. 239 ; Cushman, 1915, 71(5), p. 54, pl. 22, fig. 2 ; *Globorotalia menardii* Cushman, 1931, 104(8), p. 91, pl. 17, figs. 1 *a-c* ; Sethulekshmi Amma, 1958, p. 17, pl. 1, fig. 28 *a, b, c* ; Ganapati & Satyavati, 1958, pl. 5, figs. 136, 137.

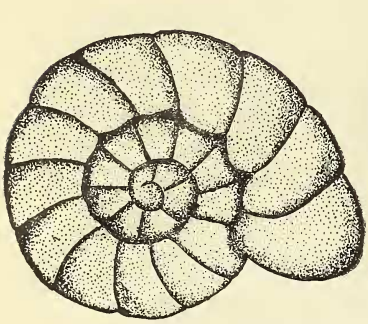
Description : Test planoconvex and compressed with usually two convolutions, the outer whorl composed of about five chambers. Sutures limbate above and depressed below. Periphery somewhat lobulated. Wall finely punctate. Aperture situated on the ventral side at the inner margin of ultimate chamber opening into the umbilical region.

Diameter : 0.33 mm.

Locality : Station C.



Figs. 69-77: 69. *Rotalia beccarii*; 70. *Rotalia venusta*—(a) dorsal view, (b) ventral view; 71. *Pulvinulina concamerata*; 72. *Pulvinulina oblonga* (Williamson) var. *scabra*; 73. *Pulvinulina punctulata*; 74. *Globigerina bulloides*—(a) dorsal view, (b) ventral view; 75. *Globigerina dubia*; 76. *Globigerinella aequilateralis*; 77. *Globorotalia menardii*.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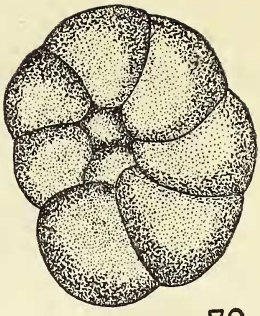
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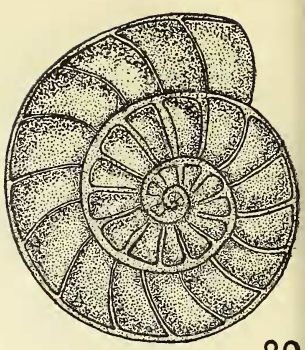
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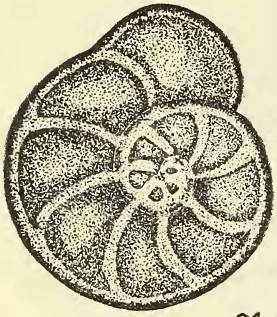
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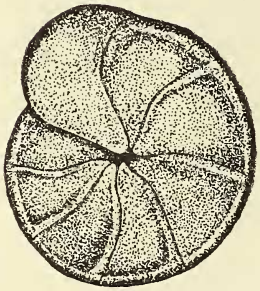
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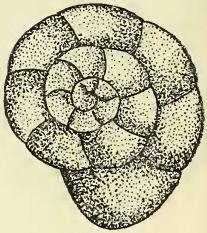
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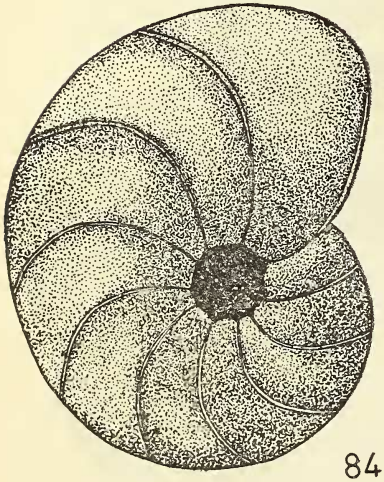
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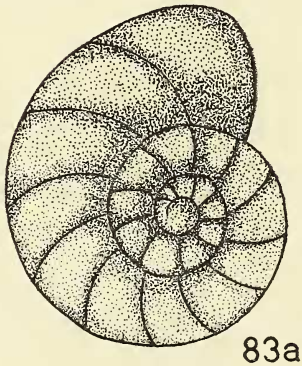
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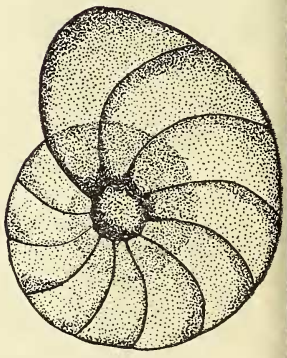
83b

0.2 mm
Figs. 78-80, 83

0.1 mm
Figs. 81, 82, 84

Figs. 78-84 : 78. *Anomalina ammonoides* ; 79. *Anomalina coronata* ; 80. *Palmerinella palmerae* ; 81. *Cibicides refulgens*—(a) dorsal view, (b) ventral view ; 82. *Cibicides lobatulus* ; 83. *Cibicides pseudoungeriana*—(a) dorsal view, (b) ventral view ; 84. *Planulina wuellerstorfi.*

Distribution : North and South Atlantic, North and South Pacific, Hawaiian Islands, Mediterranean, Red sea, Ceylon coast and Indian seas.

Family Anomalinidae

Subfamily Anomalininae

Genus *Anomalina* d'Orbigny, 1826

Anomalina ammonoides (Reuss) (Fig. 78)

Anomalina ammonoides Brady, 1884, vol. 9, p. 672, pl. 94, figs. 2, 3 ; Brady, Parker & Jones, 1888, vol. 12, p. 228, pl. 45, figs. 20-22 ; Dakin, 1906, vol. 5, p. 239 ; Cushman, 1915, 71(5), p. 46, pl. 19, fig. 2.

Description : Test with numerous chambers set in three or four coils, the last coil composed of twelve to sixteen chambers ; chambers slightly inflated. Sutures somewhat depressed. Peripheral edge rounded. On the ventral side umbilical region depressed. Wall calcareous, coarsely foraminated. Aperture a narrow curved slit situated at the base of margin of last chamber.

Diameter : 0·34 mm.

Locality : Station A.

Distribution : North Pacific, off Hawaiian Islands, Hongkong, Chatham Island, off Guam and between Guam and Japan, Ceylon coast and Arabian sea.

Anomalina coronata Parker and Jones (Fig. 79)

Anomalina coronata Brady, 1884, vol. 9, p. 675, pl. 97, figs. 1, 2 ; Cushman, 1915, 71(5), p. 47, pl. 18, fig. 5.

Description : Test biconvex with few chambers, the umbilical region depressed on both faces. Final whorl of test composed of eight inflated chambers. Wall coarsely perforated. Aperture a long curved slit placed obliquely on the ventral side at the inner margin of last chamber.

Diameter : 0·30 mm.

Locality : Station C.

Distribution : North Pacific, Hawaiian Islands and Arabian sea.

Genus *Palmerinella* Bermudez, 1934

Palmerinella palmerae Bermudez (Fig. 80)

Palmerinella palmerae Cushman, 1959, p. 333, pl. 54, figs. 11 *a, b. c* ; Ganapati & Satyavati, 1958, p. 111, pl. 6, figs. 167, 168.

Description : Test with numerous chambers, much compressed, all chambers visible above, but only those of the last whorl below. Wall calcareous, coarsely perforated. Aperture long slit-like on the last chamber in line with the peripheral margin.

Diameter : 0·33 mm.

Locality : Station A.

Distribution : Occurs in most seas.

Subfamily Cibicidinae

Genus *Cibicides* Montfort, 1808

Cibicides refulgens Montfort (Fig. 81 a, b)

Truncatulina refulgens Brady, 1884, vol. 9, p. 659, pl. 92, figs. 7-9 ; Cushman, 1915, 71(5), p. 30, pl. 12, fig. 2. ; *Cibicides refulgens* Daniel, 1949, p. 116, figs. 85, 86; Ganapati & Satyavati, 1958, p. 111, pl. 6, figs. 161-163.

Description : Test planoconvex, ventral side much convex, dorsal side flat, chambers numerous, eight chambers in the final whorl ; the early chambers on the dorsal side indistinct. Sutures on the ventral side slightly depressed and somewhat sigmoid ; on the dorsal side sutures broad and limbate. Periphery subcarinated. Wall calcareous, finely perforated.

Diameter : 0·15 mm.

Locality : Station D.

Distribution : Indo-Pacific region, Kerimba Archipelago, Malay Archipelago, Cebu, Tawi Tawi, Makyan Island, Macassar Straits and Indian seas.

Cibicides lobatulus (Walker and Jacob) (Fig. 82).

Truncatulina lobatula Williamson, 1858, p. 59, pl. 5, figs. 121-123 ; Brady, 1884, vol. 9, p. 660, pl. 92, fig. 10 ; pl. 93, figs. 1, 4, 5 ; pl. 95, figs. 4, 5 ; Dakin, 1906, vol. 5, p. 238 ; Cushman, 1915, 71(5), p. 31, pl. 15, fig. 1 ; *Cibicides lobatulus* Cushman, 1959, p. 335, pl. 36, fig. 11.

Description : Test planoconvex with numerous chambers. All the chambers visible on the dorsal side and only those of outer whorl visible

ventrally ; outer whorl of seven or eight chambers. Sutures slightly depressed. Surface of the test smooth, coarsely punctate or covered with slight protuberances. Aperture a narrow slit situated ventrally at the base of the final chamber.

Diameter : 0·13 mm.

Locality : Station C.

Distribution : North Pacific, off Hawaiian Islands, Bering sea, Guam and between Guam and Yokohoma, off Japan, Ceylon coast and Arabian sea.

Cibicides pseudoungeriana (Cushman) (Fig. 83 a, b).

Truncatulina pseudoungeriana Brady, 1884, vol. 9, p. 664, pl. 94, figs. 9 *a-c* ; *Cibicides pseudoungeriana* Cushman, 1931, 104(8), p. 123, pl. 22, figs. 3-7 ; Daniel, 1949, p. 114, figs. 114, 145 ; Sethulekshmi Amma, 1958, p. 34, pl. 2, figs. 49 *a*, *b*.

Description : Test circular in outline, planoconvex, chambers numerous, the last formed whorl consists of ten or eleven chambers. Sutures depressed below and limbate above in the earlier chambers but become depressed in the last few chambers of the final whorl. Peripheral margin rounded. Wall calcareous and coarsely perforated. Aperture close to the peripheral margin on ventral side.

Diameter : 0·34 mm.

Locality : Station C.

Distribution : Atlantic and Indo-Pacific region.

Genus *Planulina* d'Orbigny, 1826

Planulina wuellerstorfi (Schwager) (Fig. 84).

Truncatulina wuellerstorfi Brady, 1884, vol. 9, p. 662, pl. 93, figs. 8, 9 ; Cushman, 1915, 71(5), p. 34, pl. 12, fig. 3 ; *Planulina wuellerstorfi* Cushman, 1931, 104(8), p. 110, pl. 19, figs. 5, 6 ; Sethulekshmi Amma, 1958, p. 35, pl. 2, figs. 51 *a*, *b*.

Description : Test planoconvex, many chambered, the final whorl of nine chambers. Sutures limbate. Peripheral margin rounded. Aperture an arched opening situated at the base of last chamber.

Diameter : 0·32 mm.

Locality : Station A.

Distribution : Pacific Ocean, Panama Bay, off Hawaiian and Midway Islands, Galapagos Islands, between Guam and Yokohama and Arabian sea.

General Considerations

Regional distribution of foraminiferal groups :

The regions along the Indian and adjacent coasts whose foraminiferan fauna studied in some details are (1) Laccadive region (Chapman 1895); (2) Gulf of Cambay region (present investigations) ; (3) Travancore coast off Arabian Sea (Sethulekshmi Amma 1958) ; (4) Bay of Bengal off Visakhapatnam coast (Ganapati & Satyavati 1958) ; (5) Gulf of Mannar off Krusadi and adjacent areas (Gnanamuthu 1943 & Daniel 1949) ; (6) Gulf of Mannar off Ceylon coast (Dakin 1906). From the above six regions a total number of thirty families representing various species of Foraminifera are on record, they being Astrorhizidae, Rhizamminidae, Saccamminidae, Hyperamminidae, Reophacidae, Ammodiscidae, Lituolidae, Textularidae, Verneuilinidae, Valvulinidae, Silicinidae, Miliolidae, Ophthalmidiidae, Trochamminidae, Lagenidae, Polymorphinidae, Nonionidae, Camerinidae, Peneroplidae, Buliminidae, Rotaliidae, Amphisteginidae, Calcarinidae, Cymbaloporidae, Cassidulinidae, Chilostomellidae, Globigerinidae, Globorotaliidae, Anomalinidae, and Planorbulinidae.

Of the above families Astrorhizidae, Textularidae, Miliolidae, Lagenidae, Nonionidae, Buliminidae, Rotaliidae, Globigerinidae, and Anomalinidae are common to all the six regions. From the Laccadive region a larger number of families has been recorded. The only families not so far known from this region are Rhizamminidae, Hyperamminidae, and Silicinidae. This region is also characterised by the presence of members of the families Ammodiscidae, and Chilostomellidae which are not known from any of the other five regions. The foraminifera fauna of the Travancore coast is represented by twenty-one families. Rhizamminidae, Hyperamminidae, Reophacidae, Ammodiscidae, Silicinidae, Polymorphinidae, Calcarinidae, Cassidulinidae and Chilostomellidae are not on record from this region.

Visakhapatnam region is characterised by the members of the family Silicinidae which is not known from other regions. Reophacidae, Ammodiscidae, Valvulinidae, Calcarinidae, Cymbaloporidae and Chilostomellidae are not on record.

In the Gulf of Mannar off Krusadi including adjacent areas and Ceylon coast, the families Rhizamminidae, Ammodiscidae, Valvulinidae, Silicinidae, Trochamminidae, Cassidulinidae and Chilostomellidae are not known.

In the present investigation, from the Gulf of Cambay region fifteen families have been recorded. Species recorded in the Gulf of Cambay region but not known from any of the other five regions are (1) *Quinqueloculina candeiana* d'Orbigny, (2) *Spiroloculina antillatrum* d'Orbigny *aequa* Cushman, (3) *S. depressa* var. *rotundata* Williamson, (4) *Biloculina*

lucernula Schwager, (5) *Nodosaria subperversa* Cushman, (6) *Nonion depressula* (Walker & Jacob), (7) *Bolivina nitida* Brady, (8) *Bolivina aenariensis* (Costa), (9) *Rotalia venusta* Brady, (10) *Pulvinulina concamerata* Montagu, (11) *P. oblonga* var. *scabra* Brady, and (12) *Anomalina coronata* Parker & Jones.

Nature of Sediments in stations and species abundance :

The distribution of the Foraminifera appears to have some relationship to the type of bottom deposits. The sediment sample from Station A which is an admixture of mud and a large amount of coarse sand, has very rich foraminiferal fauna well represented both by the number of species and abundance of specimens. Miliolidae are dominant followed by Rotaliidae, Nonionidae and Textulariidae in the order of abundance. Arenaceous forms belonging to the family Textulariidae are common and lagenids are also found in the same frequency. Among the rotalids the most common are *Rotalia*, *Cibicides* and *Discorbis*. The large sized forms like *Nodosaria*, *Spiroloculina* and *Textularia* are abundant. Planktonic Foraminifera like *Globigerina bulloides*, *G. dubia* are present with the former being most common. All specimens are well preserved in the sediment with the exception of a few which have been found worn-out and damaged.

In Station B where the texture of the sediment is of very fine particles of mud, small forms like *Bulimina*, *Eggerella* and *Lagena* are most common. The station is poor in the abundance of specimens. Miliolids and Rotalids are sparsely present. Arenaceous forms are lacking. Planktonic forms of the genera *Globigerinella* and *Globigerina* have been observed. *Globigerina dubia* is most abundant and *Globigerinella aequilateralis* very rare.

The sediment from Station C which is slightly rough being composed of a fair amount of mud with a small proportion of sand has foraminifera represented by Rotaliidae, Miliolidae Nonionidae, Camerinidae, Textulariidae and Peneroplidae. Specimens from this station have been found to be in a good state of preservation. Planktonic forms are represented by *Globigerina bulloides*, *G. dubia*, and *Globorotalia menardii*.

In Station D where the sediment is muddy, the fauna is extremely poor. *Bulimina* and *Bolivina* are common. Miliolids and Rotalids are uncommon. Planktonic forms are represented by *Globigerina bulloides* and *G. dubia*.

In general, the foraminifera of the Gulf of Cambay are typical of shallow tropical warm waters of Indo-Pacific region.

Summary

1. Eighty-four species of Foraminifera belonging to 34 genera under fifteen families viz., Astrorhizidae, Textularidae, Valvulinidae,